Lidar Ratios for Dust Aerosols Derived from Retrievals of CALIPSO Visible Extinction Profiles Constrained by Optical Depths from MODIS-Aqua and CALIPSO/CloudSat Ocean Surface Reflectance Measurements.

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Introduction

CALIPSO's (Cloud Aerosol Lidar Infrared Pathfinder Satellite Observations) analysis algorithms generally require the use of tabulated values of the lidar ratio in order to retrieve aerosol extinction and optical depth from measured profiles of attenuated backscatter. However, for any given time or location, the lidar ratio for a given aerosol type can differ from the tabulated value. To gain some insight as to the extent of the variability, we here calculate the lidar ratio for dust aerosols using aerosol optical depth constraints from two sources. Daytime measurements are constrained using Level 2, Collection 5, 550-nm aerosol optical depth measurements made over the ocean by the MODIS (Moderate Resolution Imaging Spectroradiometer) on board the Aqua satellite, which flies in formation with CALIPSO. We also retrieve lidar ratios from night-time profiles constrained by aerosol column optical depths obtained by analysis of CALIPSO and CloudSat backscatter signals from the ocean surface [Ref. 1].

Theory

For correctly calibrated signals, the particulate lidar ratio, S_P, can be related to the particulate optical depth of a layer, τ_P, multiple-scattering correction factor, η, and integral over the depth of the layer of the attenuated, particulate backscatter, γ'_P, by the following equation (adapted from Ref. [2]):

$$S_P = \left(1 - \exp\left(-2\eta\tau_P\right)\right) / 2\eta\gamma'_P \qquad (1)$$

However, as the layers studied here are in contact with the surface, it is not possible to evaluate γ'_P directly from the attenuated backscatter signal and, therefore, it is also not possible to derive S_P analytically from (1). It must, therefore, be obtained by an iterative process during the retrieval of the particulate extinction and backscatter profiles.

Method

1. Select overpass regions where strong dust layers have advected over ocean,
2. Average CALIPSO Level-1 attenuated backscatter data to 5-km horizontal resolution,
3. Calculate average MODIS (or ocean surface reflectance method) aerosol optical depth (AOD) over the CALIPSO 5-km path,
4. Assume all aerosol resides in surface layer,
5. Assume lidar ratio and η are constant throughout the layer,
6. Renormalize averaged attenuated backscatter profiles above the layer top to account for attenuation by the overlying atmosphere,
7. Retrieve particulate extinction profile though the layer, adjusting lidar ratio iteratively until the retrieved optical depth matches that from MODIS or the surface reflectance measurements. (i.e. a constrained retrieval).

Results

Particulate backscatter (row d), extinction (e) and lidar ratio (g) retrievals obtained using AOD (f) constraints from MODIS on January 1st and 3rd 2007 are presented below in columns 1 and 2 respectively. Results obtained using ocean surface reflectance (SODA) measurements on January 2nd and 4th 2007 appear in columns 3 and 4. The 532-nm attenuated backscatter data appear in row (a) (with CALIPSO's orbit shown in the inset) and CALIPSO's Cloud-Aerosol Vertical Feature Mask in (b) and Aerosol Type Mask in (c).

The occasional black stripes and missing data from the lower panels result from AOD constraints that were unavailable over the land or in cloudy regions.

During the period shown dust was being advected over the ocean from the African continent.

The mean lidar ratios for January 1st – 3rd are in the range 35 – 45 sr and compare well with CALIPSO's standard value for dust of 40 sr. On January 4th, the mean value is around 53 sr. The higher value can be explained by the mixing of smoke with the dust to create "polluted dust" (see panel (c) and can be compared with CALIPSO's standard value of 55 sr.

References

1. Josset, D., J. Pelon, A. Protat, and C. Flamant (2008), New approach to determine aerosol optical depth from combined CALIPSO and CloudSat ocean surface echoes, *Geophys. Res. Lett.*, **35,** L10805, doi:10.1029/2008GL033442.
2. Fernald, F. G., B. M. Herman and J. A. Reagan (1972). Determination of Aerosol Height Distributions by Lidar, *J. Appl. Meteor.* **11**, 482-489.